LOCATION SIGNALING FOR LARGE-SCALE, END-TO-END, QUALITY-OF-SERVICE MONITORING OF MOBILE TELECOMMUNICATION NETWORKS

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BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates generally to mobile telecommunication networks. More particularly, and not by

10   way of limitation, the invention is directed to a location-signaling system and method for large-scale end-to-end quality-of-service monitoring of packet-switched telecommunication networks.

15   Description of Related Art

The detailed analysis of live General Packet Radio System (GPRS) and UMTS networks is of increasing importance as traffic on these networks increases and traffic measurements become available. Traffic measurements from

20   these networks are extremely useful when analyzing such areas as network utilization information, network performance information indicating whether the users are getting what they paid for or what they expect, bottleneck information identifying bottlenecks in the network, system

25   enhancement information for enhancing the network so that identified problems are eliminated, and dimensioning information for re-dimensioning of cells, links, and the like.

In the case of a circuit-switched service such as voice,

30   for example, it has conventionally been sufficient to measure the call intensities, call durations, and the ratio of blocked calls to successful calls. In the case of

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packet-switched services such as Web browsing, File Transfer Protocol (FTP) services, e-mail, Multimedia Messaging Services (MMS), and the like, the above tasks are not at all trivial because the end-to-end or user-perceived performance depends on the interaction of many protocols at different interfaces and on various protocol layers. Furthermore, the use of shared resources leads to rather complicated queuing phenomena, which are difficult to model and analyze.

It is envisioned that measurement-based network analysis will soon become a primary tool for the network operator. In order to perform the measurements in a cost-effective manner, the measurement equipment should be inexpensive, and the number of measurement points should be limited to reduce equipment costs and to minimize having to synchronize measurements taken at different points in the network.

Measurement-based characterization of GPRS networks has been described in a document entitled, "Wireless Service Usage and Traffic Characteristics in GPRS networks", by Roger Kalden, Tamás Varga, Bianca Wouters, and Bart Sanders (18th International Teletraffic Congress, Berlin, Germany, 31 August through 5 September 2003). In this document, packets on the so-called Gi interface are captured. The Gi interface connects the Gateway GPRS Support Node (GGSN) with external packet data networks and service providers such as Internet Service Providers (ISPs). Based on the Gi traffic traces, detailed traffic and end-to-end performance analysis results are delivered to operators. In order to identify user sessions (i.e., which user the packets belong to), communications between the GGSN and a Remote Authentication Dial-In User Service (RADIUS) server are also monitored.

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When it is also desired to relate the end-to-end quality measurements and traffic load measurements to cells, this can be accomplished by capturing cell-level location information. Concerning the availability of this location information, two types of networks can be differentiated. In the first network type, the cell-level location information is only available in the radio access network (network of base stations and their controllers), while in the second network type, the cell-level location information is also available in the core network (network connecting access networks and other service networks).

For example, the mobility management architectures of GPRS and UMTS are different. In order to track the mobile stations, the cells in a GPRS/UMTS service area are partitioned into several groups. To deliver services to a mobile station, the cells in the group covering the mobile station page the mobile station to establish a radio link. To detect a location change of a mobile station, the cells broadcast their cell identities. The mobile station periodically listens to the broadcast cell identity, and compares it with a cell identity stored in the mobile station's buffer. If the comparison indicates that the location has changed, then the mobile station sends a location update message to the network.

In the GPRS/UMTS (R'99), procedures such as Attach, Paging, and Location Update are defined separately for circuit-switched and packet-switched services. In the circuit-switched domain, cells are partitioned into location areas. Visiting Location Registers (VLRs) track the location area of the mobile station. In the packet-switched domain, the cells are partitioned into routing areas. A

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routing area is typically a subset of a location area. The SGSN tracks the routing area of the mobile station.

In GPRS, the SGSN also tracks the cell of a mobile station when packets are delivered between the mobile station and the SGSN. In UMTS, the cells in a routing area are further partitioned into UMTS Terrestrial Radio Access Network (UTRAN) routing areas (URA). The UTRAN tracks the URA and the cell of the mobile station.

In the evolution from GPRS to UMTS, the UTRAN radio access network has been introduced, and radio-related mobility management is moved from the core network to the UTRAN as described in "3GPP TS 23.060 V3.14.0, General Packet Radio Service, Service Description, Stage 2, Release 1999, 2002-12". This means that cell-level and URA-level location information is not communicated towards the core network.

Cell-level location information can be captured from the Radio Resource Control (RRC) protocol at the so-called Iub interfaces between the base stations and the Radio Network Controller (RNC), or by extracting the information from the RNC. Both solutions, however, have disadvantages. Firstly, in the UTRAN, the number of Iub links can be rather high. Since reliable statistical analysis of a network requires a large amount of network-wide data, the first solution would be rather complicated. The number of measurement points would be rather high, and the problem of collecting and merging measurement data from these points to the data processing location would have to be solved. The second solution suffers from the disadvantage that users are identified in RRC cell-update signaling by temporary IDs (i.e., cell radio network temporary identity (RNTI) and UTRAN RNTI). The time-varying nature of these IDs makes it

difficult to associate the transactions measured at higher aggregation points with a mobility pattern tracked in an RRC trace. Furthermore the needed information in the RNCs is stored in a vendor-specific manner. Therefore, a
5   measurement system that can be used in any type of UTRAN cannot be based on extracting information from the RNC. Yet another drawback is that, in order to ensure network security, safe operation of network nodes, and the like, operators typically do not allow for measuring teams (which
10 may be external) to access important network nodes such as the RNC. Therefore, a solution with passive tapping at a standardized network interface is favored.

Thus there is a particular need for a cost-effective passive monitoring method that can be applied in the current
15 mobility management architecture of UMTS networks.

SUMMARY OF THE INVENTION

The present invention is directed to a location-signaling system and method for large-scale end-to-end
20 quality-of-service monitoring of packet switched telecommunications networks. The invention is especially useful for Universal Mobile Telecommunications System (UMTS) networks in which the detailed mobility information is only available in an access network where the level of
25 aggregation is not sufficient for reliable passive measurement-based characterization. An important advantage of the invention is that only a few measurement points are needed. It is also advantageous that the existence of the cell-level location information in the UTRAN-to-core-network
30 communication can be switched off in regular operation so that no extra load is generated in the network, and the operation of the network is left unchanged.

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Accordingly, it is an object of the invention to enable cost-efficient collection of cell-level location information in the current mobility management architecture of mobile networks, especially UMTS networks.

The invention communicates cell-level location information towards the core network, and this information is later used by passive monitoring devices.

For a hard handover, the identity of the new cell is communicated towards the SGSN over the Iu interface. For a soft handover (i.e., for handover between dedicated channels), the identities of the cells in the new active set are communicated towards the SGSN over the Iu interface. Preferably, this information is added to user-plane packets only after a change in the cell information is observed by the RNC. In one embodiment, the cell-level location information is carried in the GPRS Tunneling Protocol (GTP) Extension Header described in "3GPP TS 29.060 V3.7.0, GPRS Tunneling Protocol across the Gn and Gp Interface, Release 1999, 2002-12". Initially, the information may be a vendor-specific extension. If a node does not understand a certain extension in the header, the node answers with a list of extensions that are known by the node. Therefore the introduction of a new extension header does not cause interoperability problems.

In one exemplary embodiment, the transmission of cell-level location information can be switched off. In this way, the transmission of cell-level location information is active only during measurements.

In another exemplary embodiment, the cell-level location information is also forwarded on the Gn interface within the core network. In this case, the number of needed measurement points may be further decreased. The cell-level

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location information may also be encrypted before forwarding, and then decrypted in the monitoring device.

Thus, in one aspect, the invention is directed to a method of measuring packet-switched traffic in a packet-
5   switched radio telecommunication network. The network includes a mobile station linked to a base station through a radio channel. The base station is linked to a radio access network, and the radio access network is linked to a support node in a packet core network. The method includes the
10 steps of obtaining cell-level location information of the mobile station in a node in the radio access network; adding the obtained cell-level location information to user-plane packet headers; and transmitting the user-plane packets carrying the cell-level location information towards the
15 packet core network. The cell-level location information is combined with packet data protocol (PDP) context information at a packet core network level. This is followed by measuring the cell-level location information (and other information, for example, the PDP context information) at
20 the packet core network level.

In another aspect, the invention is directed to a method of measuring packet-switched traffic in a Universal Mobile Telecommunications System (UMTS) packet-switched radio telecommunication network having a plurality of mobile
25 stations linked to a plurality of base stations through a plurality of radio channels. Each of the base stations is linked to a UMTS Terrestrial Radio Access Network (UTRAN), and a plurality of UTRANs are linked to a Serving General Packet Radio Service (GPRS) Support Node (SGSN) in a packet
30 core network through an Iu interface link. The packet core network, in turn, is linked to a Gateway GPRS Support Node (GGSN) through a Gn interface link. The method includes the

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steps of passing cell-level location information for the mobile stations and PDP context information from the plurality of UTRANs to the SGSN via the Iu interface, or to the GGSN via the Iu interface links, the SGSN, the packet core network, and the Gn interface link. User-plane traffic for the entire network, including cell-level location information for the mobile stations and PDP context information combined from the plurality of UTRANs, is then measured on the Iu or the Gn interface link, respectively.

In yet another aspect, the invention is directed to a mobile telecommunication network for exchanging data packets. The telecommunication network includes an access network portion for connecting a plurality of mobile stations to the telecommunication network, a packet core network portion for connecting the access network portion to external networks, and at least one network monitoring device. The telecommunication network is characterized by the access network portion including nodes for transmitting data packets from the mobile stations towards the packet core network portion, wherein at least one of the nodes adds cell-level location information to the data packets that are transmitted towards the packet core network portion. In addition, the monitoring device is placed at a point in the telecommunication network where the monitoring device measures cell-level location information aggregated from a plurality of nodes.

In still yet another aspect, the invention is directed to a monitoring device for measuring and analyzing packet-switched traffic in a packet-switched radio telecom-munication network. The monitoring device includes at least one measurement point for measuring cell-level location information of the mobile stations at a level in the network

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where the cell-level location information of a plurality of
mobile stations is aggregated; and computing means for
analyzing the measured aggregated cell-level location
information. The monitoring device may also include means

5   for obtaining PDP context information for the packet
switched traffic and analyzing the PDP context information
together with the measured cell-level location information
for the entire network.

10   **BRIEF DESCRIPTION OF THE DRAWINGS**

     In the following, the essential features of the
invention will be described in detail by showing the prior-
art and two preferred embodiments, with reference to the
figures of the attached drawings.

15   FIG. 1 is a block diagram showing a possible
measurement arrangement according the location unaware
prior-art solution.

         FIG. 2 is a block diagram showing a possible
measurement arrangement according the location aware prior-

20   art solution.

         FIG. 3 is a block diagram depicting the preferred
embodiment of a telecommunications network to be analyzed.

         FIG. 4 is a block diagram depicting another embodiment
of a telecommunications network to be analyzed.

25   FIG. 5 is a flow chart showing the steps of the method
of analyzing the network.

         FIG. 6 is an exemplary bitmap illustrating the outline
of a GTP header.

         FIG. 7 is an exemplary bitmap showing the outline of an

30   Extension Header Format.

         FIG. 8 is an exemplary Cell-Level Location Information
Extension Header.

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DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1, an exemplary telecommunication network is shown according to the location unaware prior art solution, where mobile stations 1 communicate with base stations 2 through radio channels. The base stations are grouped to Radio Network Controllers 5, which are connected to a 3G SGSN 7 through Iu interfaces 6. The 3G SGSN is linked to a packet core network 9 and to a GGSN 10 through Gn interfaces 8. The GGSN is linked to a corporate network 12 and to an ISP network 13 through Gi interfaces 11. Additionally, two Wireless Application Protocol (WAP) Gateways 14 are connected to the ISP network. Measurement point 15 is attached to a link between the GGSN 10 and the ISP network 13, thereby accessing session information from the network.

The session management information in both GPRS and UMTS is communicated between the mobile stations and the core network (i.e., the network containing the SGSNs and GGSNs), and the relevant information (i.e., the PDP context) is available at the Gi interface, which aggregates the traffic of a large number of users. This prior art solution can be used to deliver network wide performance statistics. These statistics do not depend on the location of the data transfer.

In FIG. 2, an exemplary telecommunication network is shown according to the location aware prior art. The network illustrated in FIG. 2 is similar to the network of FIG. 1 as far as the relations of the 3G SGSN 7, the packet core network 9, the GGSN 10, the corporate network 12, the ISP network 13, the WAP gateways 14, the mobile stations 1, and the base stations 2 are concerned. Measurement points 15a of a monitoring system 4 are attached to each link

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between the base stations 2 and the RNCs 5, thereby
accessing cell-level location information from the UTRAN.

In this case, the cell-level location information is
not sent on the Iu and Gn interfaces, and therefore the
5   number of required measurement points 15a may be very high.
In order to synchronize the traces collected at different
measurement points 15a, the measurements are executed in
parallel. This means that a simple solution, such as
connecting a laptop equipped with the necessary tapping
10   hardware and software to a measurement point, is not
feasible.

FIG. 3 is a block diagram depicting the preferred
embodiment of a telecommunications network to be analyzed.
Network elements are the same as shown in FIG. 2. In this
15   embodiment, the cell-level location information (cellinfo)
is obtained in the radio network controller (RNC) (not
shown) in the UTRAN. The RNC is responsible for tracking
the mobility of users, but normally keeps this information
for its own use. In the present invention, the cell-level
20   location information is added by the RNC to user data
packets, and is then forwarded toward the packet core
network. The packets are forwarded over the Gn interface 8,
so one measurement point 15b at the Gn interface is
sufficient.

25   FIG. 4 shows an exemplary telecommunication network
according to one embodiment of the present invention.
Network elements are the same as shown in FIG. 3 In FIG. 4,
two UTRANs 3 are linked to the 3G SGSN 7 through Iu
interfaces 6. Measurement points 17 are attached to the Iu
30   interfaces thereby accessing cell-level location information
(cellinfo) from the UTRANs at a higher aggregation level

than the measurement points 15 in FIG. 2. Monitors 16 are connected to the measurement points 17.

As shown, the cell-level location information is signaled on the Iu interface link 6 between the UTRAN and
5   the 3G SGSN, so measurement points 17 are needed on the Iu interface link 6 to collect the cell-level location information.

In GSM/GPRS networks, a mobile station communicates with only a single cell at a time. In CDMA-based networks,
10   however, a mobile station may communicate with several cells at a time. These cells may be associated with one or more base stations. In the former case we speak about "softer" handover, while the latter is called "soft" handover.

When collecting cell-level traffic statistics in
15   Wideband CDMA networks, packets transmitted during soft or softer handover can be taken into account by signaling the active set (AS) (i.e., the set of connected cells) after a change in the active set has occurred. Therefore, in the present invention, the following information may be
20   communicated towards the core network:

	Cell id	*Cell id*	*Flag*	*Meaning*
Soft handover	Cell ID	–	ADD	Cell with "Cell ID" added to AS
	Cell ID	–	DROP	Cell with "Cell ID" dropped from AS
	Cell ID_1	Cell ID_2	REPLACE	Cell with "Cell ID_1" replaced by cell with "Cell ID_2" in the AS
Hard handover	Cell ID	–	REPLACE	Hard handover to cell with "Cell ID"

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If the network operator makes the measurement in its own network, it is easy to create a post-processing tool, which encrypts all the sensitive location information before
5   analysis, as it is done today with, for example, the International Mobile Subscriber Identity (IMSI). In order to prevent the unauthorized seizure of this information via eavesdropping over the interface, the particular interface may be IPSec tunneled, or the information may be encrypted
10   in the GTP header.

FIG. 5 is a flow chart showing the steps of the method of analyzing the network. At step 21, cell-level location information of the mobile stations is observed. At step 22, the cell-level location information is added to the user-
15   plane packet headers. At step 23, the cell-level location information is transmitted towards the packet core network. At step 24, the cell-level location information, user traffic, and the PDP context information are measured at a higher aggregation level. Finally, at step 25, user-plane
20   traffic from the entire network is analyzed, including cell-level location information and PDP context information.

FIGS. 6-8 outline one possible embodiment of the invention for carrying the cell-level location information in a UMTS network using standardized features of the GTP
25   protocol.

FIG. 6 is an exemplary bitmap illustrating the outline of a GTP header. As described in 3GPP TS 29060, the GTP header is a variable length header used for both the GTP-C and the GTP-U protocols. There are three flags that are
30   used to signal the presence of additional optional fields. Important for this invention is the so called 'E' flag 26, which is used to signal the presence of an Extension Header

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field. The Extension Header field is used to enable future
extensions of the GTP header as defined herein, without the
need to use another version number. If, and only if, one or
more 'E' flags are set, the Extension Header will be
5   present. The 'E' flag indicates the presence of a
meaningful value of the Next Extension Header field. When
the 'E' flag is set to '0', the Next Extension Header field
is either not present, or if present, is not to be
interpreted. When the 'E' flag is set to '1', the Next
10   Extension Header field is present, and shall be interpreted,
as described below. The Next Extension Header Type field 27
defines the type of Extension Header that follows this field
in the GTP-PDU. Outline of the GTP header indicating the
exact location of the 'E' flag 26 and the Next Extension
15   Header Type field 27 is shown in the figure.

FIG. 7 is an exemplary bitmap showing the outline of an
Extension Header Format. The Extension Header Length field
28 specifies the length of the particular extension header
in 4 octets units. The Next Extension Header Type field 29
20   specifies the type of any extension header that may follow a
particular extension header. If no such header follows,
then the value of the Next Extension Header Type field 29
shall be '0'. To indicate the presence of cell-level
location information, the value of the Next Extension Header
25   Field may be set to '00000011'. The length of the Extension
header is defined in a variable length of 4 octets, i.e. m+1
= n*4 octets, where n is a positive integer.

FIG. 8 is an exemplary Cell-Level Location Information
Extension Header. Fields for Cell Identifier of the
30   REPLACED cell 30 are present if the Cell Change Type Flag 31
indicates 'REPLACE'. The identified cell is the cell being

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replaced in the active set. The detailed coding of the Cell Identifier is as follows:

	8	7	6	5	4	3	2	1
octets 1-6	Octets 1 to 6 contain the value part (starting with octet 2) of the Routing Area Identification IE defined in 3GPP TS 04.08, not including 3GPP TS 04.08 IEI							
octets 7-8	Octets 7 and 8 contain the value part (starting with octet 2) of the Cell Identity IE defined in 3GPP TS 04.08 not including 3GPP TS 04.08 IEI							

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The value of the Cell Change Type flag 31 is coded as follows:

Value	Meaning
00000001	ADD
00000010	DROP
00000011	REPLACE

10   Although two preferred embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing Detailed Description, it is understood that the invention is not limited to the embodiment disclosed, but is capable of numerous

15 rearrangements, modifications, and substitutions without departing from the scope of the invention. For example, although embodiments are described above with reference to UMTS communications network, the present invention is

applicable to any type of mobile telecommunications network.
The specification contemplates any all modifications that
fall within the scope of the invention defined by the
following claims.

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